

# Visual Reinforcement of Illusory Rotations: Habituation to Motion Sickness during Centrifugation

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## Introduction

- Artificial gravity through centrifugation is currently the only countermeasure providing an "Earth-like" solution to weightless health hazards.
- Available centrifuges require the subjects to endure high-speed rotations, causing motion sickness.
- Motion sickness occurs when individuals are exposed to passive motion inducing a mismatch between actual and expected sensory inputs.
- During centrifugation a mismatch occurs at every head movement as they induce illusory rotations that conflict with the perceived direction of gravity.
- Habituation protocols abate conflicts by reducing response to rotation with prolonged exposure to mismatches.
- This means that the brain fails to learn how to interpret the signals describing self-motion in artificial gravity environment.

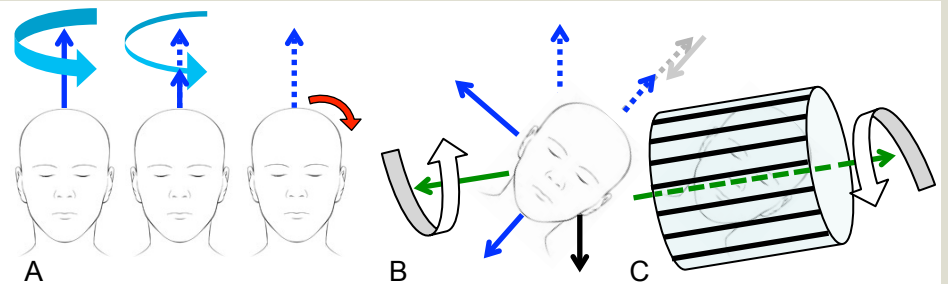
## Main hypothesis and novel habituation strategy

Habituation protocols are based on repetitions of conflicts between the illusory rotations induced at any head tilt and the stable gravito-inertial vector.

As multisensory integration weights sensory cues based on their reliability, transient angular rotation signals are suppressed as the stable estimate of gravity vector is more reliable.

Our novel habituation strategy aims at counterbalancing the priority of gravity by adding visual rotation (optokinetic stimulus), which sums up with vestibular input and reinforces the overall rotation input.

**Fig 3:** Schematic of the stimulus in a standard habituation paradigm (A-B – CONTROL condition) and the additional visual stimulus in our paradigm (C – TEST condition)



## Methods

### SUBJECTS\*:

CONTROL group – 5 participants (2 f; 25.4 ± 2.8 y; range 22 – 28 y)

TEST group – 6 participants (3 f; 26.7 ± 6.7 y; range 21 – 37 y)

\*2 participants dropped out due to high sickness/syncope

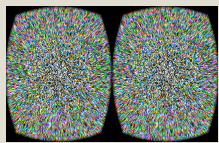
### HABITUATION STIMULUS:

Head tilt during centrifugation:

- Participant seated upright, facing outward
- 110°/s, 2.15 m radius (1 g @feet)
- 20°-30° clockwise head roll tilt

Two conditions:

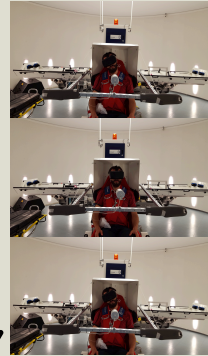
- 1) Head tilts in dark (CONTROL group)
- 2) Head tilts+visual stimulus (TEST group)



**Fig 2:** A rotating pattern of random dot was provided at every head tilt (TEST group)

Time  
0 sec  
30 sec  
60 sec  
90 sec

**Fig 1:** Each head tilt was timed



### PROTOCOL:

Two consecutive days of experiment

One day consisted of:

- 1) 3 head tilts without rotation
- 2) 3 head tilts during rotation (VORpre)
- 3) 20 minutes of free head tilts (HAB)
- 4) 3 head tilts during rotation (VORpost)
- 5) 3 head tilts without rotation

### DATA COLLECTION:

Motion sickness questionnaire (1=good, 20=vomiting):

- 1) Before the experiment
- 2) At every head tilt or every 2 minutes during the experiment
- 3) Every half-hour after the experiment

Eye movements:

60 Hz binocular video-oculography (SMI IR camera in the Oculus Rift)

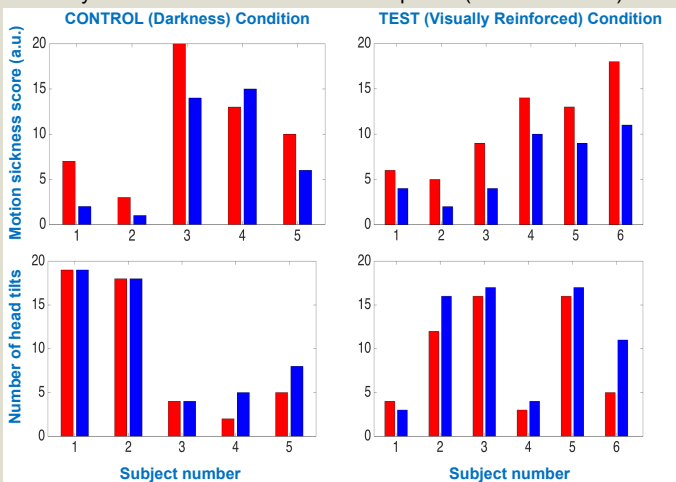
Subjective visual vertical:

- Before and after experiment
- Adjusting an arrow till it points to the sky
- Upright, 90° right and 90° left head tilts

## Results

### MOTION SICKNESS SCORE

**Fig. 4:** In both conditions participants habituated by reducing the maximal motion sickness score reached or increasing the number of tilts they could tolerate in the habituation phase (HAB2 vs HAB1).

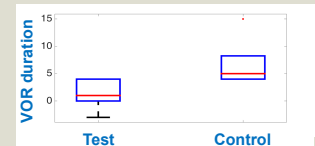


Median [MAD] score reduction - CONTROL: - 4 [2]; TEST: - 4 [1]

### EYE MOVEMENTS

Median [MAD] reduction of vertical VOR duration -CONTROL: - 5 [1] s;  
TEST: - 1 [2] s

**Fig 5:** Difference in duration of eye movement reflexive response (VOR) before day 1 and after day 2 (VORpre1 vs VORpost2)



## Conclusions

- Subjects habituate even if illusory rotation induced by head tilts is sustained by visually induced rotation sensation
- Visually reinforced habituation may induce less reduction of oculomotor response to rotation than classical habituation

➤ **Visual reinforcement of vestibular input allows habituation but may alter the way habituation is achieved**